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THE
CROONEAN LECTURES
ON
MUSCULAR MOTION,

By BROWNE LANGRISH M. D. *and* Fellow of
the ROYAL SOCIETY.

Read before the
ROYAL SOCIETY
In the Year MDCCXLVII.

Being a SUPPLEMENT to the *Philosophical
Transactions* for that Year.

There can be no greater Presumption in Favour of a Scheme,
than that it is simple, and of a Piece with the known System
of the Universe.

MEAD's *Introd. to his Essays on Poisons*, Edit. 3.

L O N D O N :

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P R E F A C E.

*I*N the Year 1733 I published an Essay on Muscular Motion, founded on the Newtonian Philosophy of Attraction and Repulsion; and though the Thoughts were hastily put together, and the Performance in general, very inaccurate, yet I must own I have not met with any Reason, since that Time, to alter my Sentiments in regard to the Cause and Manner of Contraction in the muscular Fibres.

I did not think indeed of engaging myself any further in solving such abstruse Phænomena; but being desired by my ever honoured Friend Sir Hans Sloane Baronet, to make some Experiments which might illustrate and confirm the Truth of my Hypothesis, I readily and cheerfully complied with his Commands; and afterwards I drew up the following Lectures, which were by Order of the President and Council read before the Royal Society, as the Croonean Lectures for the Year 1747.
pursuant

*pursuant to the Will of the late Lady Sadleir *.*

The Foundation of my Scheme is laid upon those Hints which Sir Isaac Newton has given us in the Queries at the End of his incomparable Book of Opticks; together with what Dr. Pemberton has said in his very learned Introduction to Cowper on the Muscles. How well it is executed is most humbly submitted to my Superiors. I do not know that I have advanced any thing inconsistent with true Philosophy; or to any of the known Laws of the animal Oeconomy. I have the Satisfaction to see, in the second Volume of the late Dr. Desaguliers's experimental Philosophy, that he approved of what I had formerly published, beyond all other Accounts of Muscular Motion; and I must confess, that meeting with Countenance from so good a Judge gave me great Encouragement to pursue the Enquiry.

** Whose first Husband was Dr. Croone, and at his Request these Lectures were founded.*

§ Page 393.

THE
CROONEAN LECTURES
ON
MUSCULAR MOTION.

LECTURE I.
SECT. I.

*Read at a Meeting of
the Royal Society, on
March 5, 1746-7.*

THE external Superficies of every Muscle, its Origin and Insertion, the Use of its Action in regard to the Animal Oeconomy, from what *Plexus* the Nerve comes, whence the Artery which supplies it arises, and to what Vein the Blood is carried, are Disquisitions very worthy the Knowledge of every *Physician* and *Surgeon*; in order to discover the true Seats and Causes of many Complaints, and to point out the most rational Methods of Cure.

II.

But as these Researches have nothing to do with the immediate Cause of Muscular Motion (the Ex-
A plication

plication of which seems to be the chief Design of the Learned *Founder* of these Lectures) I shall wave all such Enquiries, and proceed directly to investigate by what Means a Muscle so instantly and forcibly contracts itself, or shortens its Length, at the Command of the Will; and this I shall endeavour to do by such Rules and Laws as are simple, uniform, and intirely agreeable to the known System of the Universe.

III.

In order to the easier Illustration of this wonderful and important Property in the Fibres, I shall give you, *1st*, An analytical View of the component Parts of a Muscle. *2dly*, I shall shew the true Cause of Cohesion, Tension, and Elasticity in the animal Fibres. *3dly*, I shall make it appear, that every Fibre constituting a Muscle, is, in its ultimate Division, tubular, and not a Chain of Vesicles or Bladders. And, *lastly*, I shall prove it to be more than probable, that Muscular Motion proceeds from the *attractive* Quality of the constituent Particles of every Fibre being increased and strengthened by the Addition of some *athereal Matter* flying out from the Extremities of the Nerves; and that this is instantly occasion'd by the Will, and ceases again as soon.

IV.

By a chemical *Analysis* of a Muscle dissected from the Buttock of a lean Ox, which weigh'd exactly two Pounds *Averdupois*, I procured,

	Oz.	Dr.	Gr.
1. Lymph ——— ———	xxiiii	xiiii	xv
2. Volatile Salt ——— ———	i	liii	xxv
3. Oil ——— ———	ii	vi	xx
4. <i>Caput mortuum</i> ——— ———	ii	ix	v
5. Lost in Distillation, which I } presume was mostly mere Air }	—	xii	xvi
	32	00	00

V.

There being no *Averdupois* Weights in the Shops, less than Quarters of Ounces, I order'd some to be made of a Drachm, and others of two Drachms. The Drachm weigh'd 27 Grains; so that, by casting up the Grains into Drachms, and the Drachms into Ounces, we have the exact Weight of each of the above constituent Principles according to the Weight they were first of all weigh'd with.

VI.

It may be proper also to observe, that the *Apparatus* I made use of in this Process, was the same which I communicated a Description of to the *Society* some time ago, and which is since published in the *Philosophical Transactions* N°. 475; except that the Retort I now used was made of Copper, in order that I might remove it from the the Sand-Heat into the actual Fire, without unluting any Part of

the *Apparatus*, when no more Matter would arise by means of the Sand-Heat.

VII.

By this Method I could increase the Fire till the Bottom of the Retort was red-hot, without any Danger of breaking my Recipients; a Contrivance which may be useful in many chemical Processes.

VIII.

From the above-mention'd Experiment we have evident Proof of the Proportions and Qualities of the several Principles, or constitutive Parts of the muscular Fibres; and let no one be surpris'd that the watery or phlegmatic Principle abounds so much as to be nearly $\frac{1}{16}$ Parts of the whole Mass, since we know that dried Bones, and many other Things as unpromising, afford half their Weight of Water.

IX.

That the Particles of Water are endued with a strongly attracting Power, and are highly serviceable as a Band of Union in the Formation and Growth of every thing, animate and inanimate, is not only manifest from the great Quantity employed in the Growth of Animals and Vegetables, but also in our own manual Operations, such as making several Sorts of Glue, Pastes, Bricks, and such like, where the watery Particles prove a very durable and powerful *Copula*, and are not to be all of them separated
again,

again, even by a very intense Fire: Water is to be regenerated from Bricks and Tiles after they have been burnt in the Kiln.

X.

The driest Wood, Part of a Mahogany-Table, which had stood by the Fire many Years, being rasped and put over the Fire in a Copper Retort, afforded a considerable Quantity of Water.

XI.

In short, take away the Water from the most solid animal and vegetable Bodies, and they immediately become mere Dust.

XII.

I don't apprehend that this considerable Quantity of Water, which is to be procured from such solid Substances as Bricks, Wood, or even from the muscular Fibres, remains in distinct Drops or Spherules, whilst it is a Part of such solid Substances; but I conceive that the *Minima*, or primary solid Particles of Water may be attracted by, and actually joined with, the earthy, saline, and other component Particles, so as to compose the several Degrees of Hardness, according to their respective Proportions and Qualities; and when these several constituent Principles are disunited again, by the Power of Fire, or by the Length of Time, they rise up into the Air, or into
the

the Recipient, according to their Divisibility and Levity; first Water, next Salt, then Oil.

XIII.

Nature seems to delight in Transmutations. Many Kinds of Fluids are easily converted into dense Bodies. We all know how soon Water is capable of being turn'd into a very solid friable Stone, by the Power of Cold. Mercury also is easily turn'd into a hard brittle Metal; and both these return to their former State of Fluidity by means of Heat. And a Solution of Copper in Spirit of Nitre being pour'd on Oil of Tartar, both Liquids instantly become Verdigrease in a dry Powder.

XIV.

From what has been said we may observe, that Water, or the watery Particles not only make up much the greatest Part of the muscular Fibres, but, by mutually attracting, and being attracted by the other component Particles, they greatly contribute towards their Cohesion and Elasticity; for a fluid Particle will be fixed, and become a Part of a Solid, as soon as there is an attractive Force sufficient to effect its Cohesion with the other solid Parts, though it returns to its former State of Fluidity upon the Analysis of the compounded Body.

XV.

I would not by this be understood as if I design'd to exclude the other Principles from their Share
which

which they give to the true Degree of Firmness and Elasticity in the Fibres; the saline, sulphureous, and earthy Parts are all endued with a strongly attracting Power; and when brought into Contact with each other, or with the watry and aerial Particles, they give Firmness and Solidity to the Composition.

XVI.

Water seems to be the *Gluten* by which the other Principles are wrought up. Too much Water in the Composition renders the Fibres soft and lax; as in Children, and anasarctous People. Too little Moisture occasions a stiff, rigid Fibre; as in old Age. There is a certain Degree of Texture and Cohesion necessary towards muscular Motion in its greatest Strength.

XVII.

I have shewn in a former Treatise *, that Air is very instrumental in fixing and uniting the other Principles which constitute an animal Fibre; for in the most solid Parts of the Body, where the Cohesion is strongest, we find great Plenty of Air. That the Air-Particles are capable of being united, and fix'd to solid Bodies, and by that means may be esteemed a Part of their Composition, we have many evident Proofs in Dr. *Hales's Analysis of the Air*; and that those Particles do in their fixed State
strongly

* Modern Theory of Physic, p. 56.

strongly attract the other component Particles, is evident, it being well known, that the most strongly repelling and elastic Particles, when in a separate State, are the most strongly attracting, when fixed to other Bodies.

XVIII.

Now, according to Dr. *Hales*, since a much greater Proportion of Air is found in the solid than in the fluid Parts of Bodies; may we not with good Reason conclude, that it is very instrumental, as a Band of Union in those Bodies; those Particles (as Sir *Isaac Newton* observes*) receding from one another with the greatest repulsive Force, and being most difficultly brought together, which upon Contact cohere most strongly? And if the Attraction or Cohesion of an unelastic Air-Particle be proportionable to its repulsive Force in an elastic State, then since its elastic Force is found to be vastly great, so must that of its Cohesion also. Let us add to this, that the Air generated from the fleshy Fibres, in the Experiment above-mention'd, was not separated without great Violence; for it did not rise in any Quantity, till the Clouds did, which contain'd and brought over the Salt and Oil: Whence it is evident that the aerial Particles are firmly fix'd, and consequently are very instrumental in the Union of the other constituent Principles.

XIX.

* Opt. Qu. 31.

XIX.

Sir *Isaac Newton* * thinks, that not only Water and Air are convertible into dense Bodies, but that even Light may become a Part of gross Bodies, and that they may receive much of their Activity from the Particles of Light which enter their Composition. It is the Opinion also of Monf. *Homborg*, that Light or Fire is a Part of the Composition of all Things; though in the Analysis of Bodies it is always lost, escaping the Skill of the Artist, and passing through the closest Vessels.

XX.

We all know that solar Fire, or Light, adds Weight to Lead, Tin, or Regulus of Antimony, when exposed to the Fire of a burning Glass, though they otherwise lose much in Smoak and Steam. But to proceed :

XXI.

These then being then the component Parts of the muscular Fibres, our next Task is to shew the Cause of their Tension and Elasticity.

XXII.

That all the muscular Fibres of the Body are in a State of Tension, during Health, is manifest from
every

* Opt. Qu. 30.
B

every Incision made across them, when the two Segments of the Muscle so divided, retire, one to its Insertion, and the other to its Origination; that is, every Fibre is always stretched out beyond its natural State of Rest or Quiescence, so that both Ends of it retract a considerable Distance after being cut asunder. Now there are two Things which seem to be principally concerned in this Affair; *viz.* the Impulse and Pressure of the circulating Fluids, always distracting the Fibres, and a constant *Nisus* or Endeavour in the constituent Particles of the Fibres to run closer together, when so distended, by means of their mutual Attraction towards each other.

XXIII.

The Equilibration which is ever preserved between the antagonist Muscles, in a healthy State, unless when the Will directs it otherwise, arises from this *Vis Restitutionis*; which being stronger or weaker according to the Degrees of Tension, and the Degrees of Tension depending upon the Velocity and Quantity of Fluids circulating through every Fibre; it follows, that as long as the Fluids have the same free Access to every voluntary Muscle, so long will the *Equilibrium* be maintained.

XXIV.

In an Essay which I publish'd on this Subject of muscular Motion, in the Year 1733, I endeavoured to prove that every the least Corpuscle of Matter is endued with an attractive Virtue on one of its Sides,
and

[II]

and a repulsive Power on the other, something similar to the Loadstone; and this I was first of all induced to believe, from what Sir *Isaac Newton* observes in his *Opticks*, *Qu.* 31.

XXV.

When any saline Liquor (*says he*) is evaporated to a Cuticle, and let cool, the Salt concretes in regular Figures; which argues, that the Particles of the Salt, before they concreted, floated in the Liquor, at equal Distances, in Rank and File; and by Consequence, that they acted upon one another by some Power, which at equal Distances is equal, at unequal Distances is unequal: For, by such a Power, they will range themselves uniformly, and without it they will float irregularly, and come together as irregularly. And since the Particles of *Iceland* Chrystal act all the same Way upon the Rays of Light, for causing the unusual Refraction, may it not be supposed, that in the Formation of this Chrystal, the Particles not only ranged themselves in Rank and File for concreting in regular Figures, but also, by some kind of polar Virtue, turned their homogeneous Sides the same Way?

XXVI.

And again, we are taught by the same *Great Man*, that Fire is the most simple of all known Bodies, and consequently the most immutable; that each Ray of Fire or Light has Sides differently affected, and which have different Properties; and that *Iceland*

Chryſtal is found to attract a Corpufcle of Fire, if one of its Sides be turned towards the Chryſtal, and repel it, if the other be; for one and the ſame Ray is here refracted ſometimes after the uſual, and ſometimes after the unuſual manner, according to the Poſition which its Sides have to the Chryſtal; and ſince the Chryſtal, by this Diſpoſition or Virtue, does not act upon the Rays, unleſs when one of their Sides of unuſual Refraction looks towards that Coaſt, this argues a Virtue or Diſpoſition in thoſe Sides of the Rays, which answers to, and ſympathizes with, that Virtue or Diſpoſition of the Chryſtal, as the Poles of two Magnets answer to one another.

XXVII.

We are fully perſuaded, that, in the Chryſtallization of Salts, they could not ſo regularly and conſtantly preſerve their peculiar Shapes, Forms, and Figures, if every Particle of them had not its determinate Poles: For granting that the component Particles of each kind of Salt have a peculiar Shape and Size, different from any other kind of Salt, yet if they had a Power of uniting with each other indifferently, at their Tops, Sides, and Bottoms, one would think they could not always coaleſce into Chryſtals of the ſame regular Figure: But if the conſtituent Particles of every kind of Salt have their determinate Poles, then they cannot poſſibly unite with each other, but when their Poles ſquare with one another, and conſequently they will always fly together, and be joined at ſuch Points, only where their correſponding Poles are; which muſt of courſe conſtantly produce the ſame regular Form and Figure

in every Aggregate of such particular saline Particles.

XXVIII.

Hence it is, that *Salt Armoniac* so elegantly imitates the Branches of a Tree; *Salt of Hartshorn* a Quiver of Arrows; *Salt of Tin* shoots into Lines like little Needles, which spread themselves every Way from a Point, as from a Centre, so as to represent a Star, &c. Now can it be imagined that these, or any other kind of Salts, would immutably and perpetually coalesce into Chrystals of the same regular Figure and Shape from any other Principle?

XXIX.

Since therefore we have so much Reason to believe that Salts of all kinds, and even the Rays of Light are endued with a polar Virtue, that is, every Corpuscle attracts on one of its Sides, and repels on the other; and since it is a well known Axiom, that *Nature is ever frugal in Principles*, I think it not at all unphilosophical, or contrary to any of the known Laws of Nature, to believe that every Particle of Matter in the World is endued with an attractive and repulsive Property.

XXX.

Thus then, if the constituent Corpuscles of the muscular Fibres are formed together according to this Law, if they are all united at particular Points

COR-

corresponding to their attractive Virtue, it follows, that wherever a muscular Fibre is stretched out to the least Degree of Tension, some of its Particles will touch each other in fewer Points; whilst others may possibly be disunited and removed from each other, though perhaps to inconceivable small Distances: Hence there will be a constant *Nisus* in the separated Particles to get together again; and this *Vis Restitutionis* will be stronger or weaker, according to the Number of Corpuscles so disjoined, and their attractive Virtue.

XXXI.

If the Power of the circulating Fluids (and I think it cannot be denied) be sufficient, from the first Beginning of the Circulation of the *Fœtus*, and so on as long as Life continues, to distend the Fibres beyond the Size they would otherwise be of, by reason of their corpuscular Attraction; this distractile Power must always be the Occasion of some Degree of Tension in them: And if, upon the Removal of this Tension, the component Particles have a Property of running closer together, and contracting the Fibres in their Length, by the means above-mention'd, this must be the true Cause of Elasticity in the Fibres.

XXXII.

Hence therefore it follows, that since the Fibres are always in a State of Distraction, by the Quantity and *Momentum* of the circulating Fluids, and as they are ever endeavouring to shorten themselves, by means of their corpuscular Attraction, their Elasticity must

must depend upon Tension; for the Fibres could have no Power to retract, or abbreviate their Length unless they were extended beforehand by some certain Force.

XXXIII.

It is not a sufficient Objection against this Scheme to say, that if we depend upon what is visible, we shall never see the dry solid Fibres, or Particles of any solid Body, once divided or drawn out of Contact, coalesce or unite again, or recover the close Contacts they had before; without some fluid Medium superadded.

XXXIV.

'Tis true, when a visible Crack or Flaw happens in any dry, hard, solid Body, such as a Steel-Spring, or a dry, rigid, wooden Bow, the Rupture will always continue, by reason the sever'd Particles cannot be brought again into the Sphere of each other's Attraction without the Intervention of some Medium; but then it does not follow from hence, that such a Spring or Bow cannot be bent at all without breaking; or that the constituent Particles, which must necessarily be displaced by such a distending Power, do not fly together again by their attractive Virtue, when removed only to such minute Distances.

XXXV.

The *Minima*, or primary Atoms of all Bodies are non-elastic, as being perfectly hard, solid, and inseparable; and therefore Elasticity must proceed from the Aggregate, or Composition of such Atoms, which,
by

by being capable of changing their Situations, according to the impressed Force; and being endued with a powerful attracting Virtue, they instantly resume their former Positions, when left to themselves to obey those Laws which the *Great Creator* hath impress'd upon them. As for Instance: Whilst a common Steel Spring, or any such elastic Body, is not extended or bent, we presume every individual Particle of it to be at Rest; that is, they are all situated, in regard to each other, according to their Poles, and embrace one another by their common Principle of Attraction; but no sooner is such a Spring bent, by some impressed Force, but many of its Particles on the convex Side, must of course touch in fewer Points, or perhaps be disjoin'd from each other, though to the most minute Distances that can possibly be; whilst other Particles, on the concave Side of the Spring, must necessarily slip upon, or be crowded over one another. Hence it will follow, that if those Particles which are separated from each other, or touch one another in fewer Points than usual, are yet so near each other as to be within their Sphere of Attraction, and not at all, or very little alter'd in regard to their Poles, they will consequently attract each other very strongly, and fly together again, as soon as the impressed Force is removed; whereas it is no unreasonable Conjecture to suppose, that those Particles on the concave Side of the Spring, which are compressed, and as it were rumpled over one another, may be so much alter'd from their former Positions, that their Poles do not now answer to each other; and if not, they will repel one another, according to their respective

Powers, till they have attain'd their former Situations, or, in other Words, till the Spring has recover'd its former Shape.

XXXVI.

The same Principles of Attraction and Repulsion are the Cause of Restitution or Elasticity in all other kind of Bodies. When a muscular Fibre is stretched out longer than usual, it is most certain that some of its component Particles must slip upon or by one another, or else be removed at exceeding small Distances from each other; so that if the impressed Force be too violent, if the Tension be carried so far as to disjoin a great Number of the component Particles beyond their Sphere of Attraction, the Fibre will continue to grow weaker and weaker till it breaks: But it is as evident, on the other Side, that when a stretched-out Fibre does not break, but retracts itself into its former Shape and Dimensions, upon the Removal of the extending Power, the Particles which were displaced return again to their proper Positions, merely by the means of their attractive Virtue.

XXXVII.

Now all this being so agreeable to those *Laws of Nature* which that divine Man Sir *Isaac Newton* has discover'd to us, I think we have good Reason to conclude it to be the true Cause of Elasticity in the animal Fibres.

XXXVIII.

The Elasticity in the Air indeed, or in Water agitated by Fire, or in all the Exhalations proceeding from the Earth, arises from the Principle of Repulsion only; for the Particles of Vapours, Exhalations, and Air, stand at a Distance from one another, and endeavour to recede as far from one another as the Pressure of the incumbent Atmosphere will admit them. No Power yet known is able to compress the Air-Particles within the Sphere of their Attraction towards each other, so as to destroy their elastic Property; and yet single primary Particles of Air are continually attracted by other Bodies, and consolidated with them, till by the Action of Fire, or Fermentation, they are separated again, and restored to their repulsive State.

XXXIX.

Hence we may observe, that Elasticity, in different kinds of Things, or in Matter differently modified, may arise from two several Causes, *viz. Attraction* and *Repulsion*; and perhaps, in many Instances, from the Influence of both at one and the same time.

XL.

Whenever any kind of Matter is actuated by Fire, by Fermentation, or dissolved by any Menstruum, so as to throw off its Particles in subtile Vapour, there
will

will be a constant Endeavour in those Particles to recede further from each other; so that the more they are confined, or compressed, the greater will be their elastic Power: Whereas in solid Bodies, this Property of Elasticity proceeds chiefly from Attraction, or a *Nisus* in the component Particles to fly back, or run into close Contacts again, whenever they happen to be stretched out, or bent, so as to touch each other in fewer Points.

XLI.

From what has been said we may deduce the following *Corollary*, viz. That whenever *Elasticity* proceeds from the Principle of *Repulsion*, as it does in Air, Vapours, &c. some *Compression* is necessary, in order to force the elastic Matter into a narrower Compass than it would otherwise possess; but when it arises from *Attraction*, as in the muscular Fibres, and all solid Bodies, some *distractile Force* is requisite to disjoin the component Particles from their usual Contacts, before it can exert its Power; and perhaps, for want of attending to this Difference, so many various Opinions may have arisen concerning the Cause of Elasticity.

XLII.

In my next LECTURE I shall consider the Shape of the muscular Fibres, and the Cause of muscular Action.

LECTURE II.

XLIII.

Read March 26. 1747. **I**N my former LECTURE I endeavour'd to explore the several constituent Principles of the muscular Fibres, and to shew the true Cause of their Cohesion, Tension, and Elasticity. In this, I hope, I shall make it appear, *1st*, That every Fibre constituting a Muscle is *tubular*, and of a *cylindrical* Shape, or very nearly such; and not a String, or Chain of Bladders, according to an *Hypothesis* which has been too long and too generally received. *2^{dly}*, That the corpuscular Attraction between the component Particles of the Fibres is so far increased and strengthen'd by the Influence of the nervous *Æther*, which is always at the Command of the Will, as to purse up and shorten every Fibre in its Length, whereby an Intumescence arises in the Belly of the Muscle, though it is contracted in its other Dimensions, so as, in the Whole, to possess less Room.

XLIV.

Being favoured with the Use of a most excellent Microscope, I made the following Experiments.

1st,

XLV.

1st, I divided some Fibres as minutely as I possibly could, from the Heart of an Ox, from a Part of the Diaphragm, from the intercostal Muscles, and from a Rump of Beef; all which were boiled to such a Degree of Tenderness, that we separated some Fibres with the Point of a Needle, which were not visible till placed under the Microscope, and even then they did not appear bigger than Hairs, though others, which looked like Hairs to the naked Eye, were magnified to the Size of Wheat-Straws. All these seem'd to be Fascicles of continued Tubes, as far as we could view them, without any Partitions or Cells.

XLVI.

2^{dly}, Upon rending a Muscle, which was taken from a Knuckle of Veal, and boil'd for four or five Hours, several of the transverse, as well as longitudinal Fibres appear'd very distinctly; which being placed under the Microscope, and having a strong focal Light cast upon them by means of a *Florence* Flask fill'd with Water, they seem'd to be shrunk up, either by being boil'd so long, or by being exposed to the Air, so that their Surfaces seem'd to be unequal and corrugated; which is what Mr. *Leeuwenhoek* * says deceived him at first, so as to make him

* *Anatom. & Contempl.* p. 43.

him think these Corrugations were so many Vesicles or Cells; but he soon discover'd his Mistake. In some of the Fibres I could plainly discern a dark List running in the Centre, from one End to the other; but what it was, I could not discover.

XLVII.

3dly. Having observed the muscular Fibres in the Leg of a Sea-Crab to divide very easily and distinctly from one End of the Muscle to the other; we placed a great many of them under the Microscope, but could not discern any thing like Partitions or Cells.

XLVIII.

In short, Mr. *Leeuwenhoek* * assures us, that the minutest Fibres that are visible to the naked Eye appear through a good Microscope to be invested with a Membrane, which includes within it not one simple Body, but a Bundle of still finer Fibres, the last, or smallest Order of which he thinks to be simple hollow Tubes.

XLIX.

This perhaps is as good Authority as we can have from the Assistance of Microscopes; but if we may be allowed to deduce our Arguments from the Analogy which the muscular Fibres bear to some other
Parts

* *Phil. Transf.* N^o. 367.

Parts of the Body, whose Shapes we are well acquainted with, the Reasonableness of this Opinion may appear yet stronger.

L.

All Anatomists agree, that the muscular Fibres have their Rise from the Extremities of the Nerves and Blood-Vessels; every Fibre being supplied by a Branch of a Nerve, and an Artery, and having also a Vein arising from it.

LI.

That the nervous *Capillamenta* are Cylinders is not denied by any one that I know of; and though the Arteries have been for a great while thought to be conical, yet the ingenious Dr. *John Stephenson* * Fellow of the *Royal College of Physicians* at *Edinburgh* hath evidently demonstrated the whole arterial System to be Cylinders, frequently divided and subdivided, still terminating in Numbers of small Cylinders, the Aggregate of which is always of greater Capacity than the Trunk or larger Cylinder before the Ramification.

LII.

May we not therefore very reasonably believe, from the Simplicity and Uniformity in all the Operations of Nature, that the muscular Fibres partake

of

* Medical Essays, Vol. V.

of the same Figure with those from whence they have their Rise; especially when such a Shape (as will appear in the Sequel) is more proper for all the Functions of a Muscle than any other whatsoever?

LIII.

I don't mean by this, that every Fibre of every Muscle is a perfect and regular Cylinder from one End to the other; many of them may be thicker in their Coats, and larger in their Bores about the Middle than towards each End, similar to the Shape of the Muscle; but what I think the most reasonable Opinion is, that the smallest *Fibrillæ* are hollow Tubes not divided into an infinite Number of Cells or Vesicles.

LIV.

The longitudinal, red, fleshy Fibres seem indeed to be contorted and bound about in many Places, with white, spiral, and transverse Ramifications of the Nerves; but I can see no Reason to believe that these nervous Filaments divide the longitudinal fleshy Fibres into several Apartments or Cells; I rather think that they only dip into the Cavities of the Fibres, in order to convey into them the *æthereal Medium*, which is contained in the Nerves.

LV.

Before the Laws of Nature, and the Animal Oeconomy were so well known as they are now, I don't wonder that the vesicular Scheme was thought a reasonable one, till it came to be examined by strict Rules and Experiments. The common Experiment of raising Weights by blowing up Bladders might seem, at first Sight, a very feasible Way of explaining muscular Motion; and without Doubt this first of all gave Birth to the vesicular *Hypothesis*.

LVI.

But the Fallacy of this Experiment was not discover'd for want of attending to the Difference between Bladders which have been already blown up, and dried, and such as are recent and supple.

LVII.

If a String of dry Bladders, which have been once distended as far as they could bear without bursting, and are now again squeezed close, and stretched out only in their Length, by means of a Weight hung at their Bottom; I say, if such a String of Bladders be blown up, it will undoubtedly distend their transverse Diameters so as to raise up the Weight: But in all tender yielding Vesicles, such as the muscular Fibres most certainly are, in their last, or smallest Order, it is well known, that if they were to be inflated with Air, or any such-like Matter, it would

D

distend

them in every Direction alike; they would grow longer as well as wider. Hence it follows, that if the abovemention'd Experiment was to be made with Bladders just as they are taken out of animal Bodies, it would not answer the Purpose, as is evident from blowing up those of *Calves*, *Hogs*, &c.

LVIII.

The muscular Fibres, it is true, are always in a State of Tension, but then this Tension is very far from being to their utmost Stretch; so that, were they to be inflated in the manner above-mention'd, every Muscle would necessarily increase in Length as well as Breadth.

LIX.

Another insuperable Difficulty belonging to the vesicular *Hypothesis*, is how to blow up a Bladder open at both Ends; which every Vesicle is supposed to be, by having a free Communication with the Blood-vessels.

LX.

Having therefore so much Reason to conclude, that the muscular Fibres, in their ultimate Divisions, are not cellular, but tubular, let us proceed to shew the Manner and Cause of their Contraction.

LXI.

A Muscle in its Motion very evidently grows less in Bulk.

This Proposition is clearly demonstrated by that famous Experiment communicated to the *Royal Society*, by Dr. *Goddard*† in the Year 1669, where putting a Man's Arm into a glass Cylinder full of Water, the Water always sunk when the Muscles of the Arm were contracted, and rise again to the first Standard when they were relaxed. This we think may be look'd upon as an *Experimentum Crucis*; whereas, if every Fibre was a Chain of Bladders, whose Contraction in Length arose from their Inflation in Breadth, all the World knows there would be a sensible Swell of the whole Arm upon muscular Action.

LXII.

There are still other Difficulties attending the vesicular *Hypothesis*. If the animal Spirits are supposed to inflate the Cavities of the muscular Fibres merely by a propulsive Force, like unto the Steam of boiling Water working in the Engine to raise Water by Fire, it ought to be proved from whence so strong an Impulse should arise; and also how the Nerves, which are the Conduits thro' which this
flatulent

† *Vide Register of the Royal Society*, Vol. IV. p. 95.

flatulent Matter must be convey'd, should lie so loose and unelastic; it being evident from all Experience, that if such an elastic flatulent Vapour was to fly thro' the whole Length of the Nerves, with an Energy sufficient to give a Man a Power of lifting up great Weights, the Nerves must be stretched out in Proportion, and consequently would be very tense and elastic.

LXIII.

Those who suppose the Inflation of the Muscles to arise from a fermentative Motion in the Fluids, ought to prove, by a proper Number of Experiments, that there are Juices existing in the Body capable of such sudden and violent Rarefactions or Explosions, upon mixing with each other; and if this possibly could be done, the Diminution of the Bulk of the Muscles in Action, would overturn all their Scheme.

LXIV.

Hence it is evident that the *vesicular Hypothesis* ought to be intirely rejected, as being repugnant to the *Laws of Matter*, and to the *Phænomena* of the Muscles.

LXV.

By undoubted Experiments we are convinced, that the Intumescence of a Muscle, when it acts, arises merely from a Change made in its Figure; that is, as it shortens in Length the Belly grows thicker, and yet the Bulk in general is diminished.

Let

Let us therefore inquire after the Agents which are capable of producing such surprising *Phænomena*, and at the same time shall be consistent with every other Operation in the Animal Oeconomy.

LXVI.

From what has been said it appears, that Contraction, or muscular Action, does not depend upon any Fluid dilating or distending the Fibres; but, on the contrary, they shrink up and grow less. The instantaneous Alternations from Constriction to Dilation, and *vice versa*, manifestly discover that muscular Motion cannot be caused by such Juices as the *Blood*, *Lymph*, and such-like; but it must be from some more subtil *æthereal* Matter, which may be mix'd with the Blood in general, and secreted from it by the Glands of the Brain.

LXVII.

Let us but carefully consider the exquisite *Apparatus* of the Brain, the Quantity of Blood it receives, the infinite Number of its excretory Ducts, and the great Divisibility and Subtily of Matter, and we shall find great Reason to conclude that there is a most subtil, *æthereal*, volatile Fluid, of great Force and Elasticity, perpetually secreted from the Blood, by the Glands of the Brain, and continually flying into the Nerves, for the Uses of muscular Motion, and many other great Purposes of the Animal Oeconomy.

LVIII.

LXVIII.

The delicate Texture of the Nerves, as well as that of the Brain, implies that the Fluid they convey to the Muscles must be exquisitely fine. Indeed when a Nerve is wounded, there flows from it a sweet, soft, clammy, balsamic Juice, which no doubt is carried, at all other times, by the evanescent Nerves to their ultimate Divisions, in order to nourish and preserve the most minute *Fibrillæ*, and all their Expansions; and this may properly be called the *Succus nutritius* of the Nerves. But I cannot conceive that this visible Juice has any thing to do with the immediate Cause of voluntary Motion; for so viscous a Matter could never admit of such sudden Vicissitudes, as are in muscular Action, if it was capable of performing it in other Respects.

LXIX.

There are Abundance of Considerations which evince the Existence of some subtil Spirit in the Nerves, much finer than to be the Object of our Senses. We have no Proof, either from Experiment or Reason, of any other instrumental or physical Cause of Sense or Motion, but this *animal Æther* which is elaborated from the Blood.

LXX.

LXX.

The learned Dr. *Mead* * thinks no Regard ought to be had to the immechanical Notions of those Authors, who imagine that there is no such thing as a nervous Fluid in an animal Body ; and that muscular Motion and Sensation are performed only by the Vibrations of the Fibres of the Nerves, without the Intervention of any spirituous Fluid.

LXXI.

The surprising Discoveries which have been made of late Years, by a Variety of Experiments upon Electricity, do in some measure give us an Idea of the great Subtilty and Velocity of the nervous Fluid. I have been informed by the ingenious Mr. *Watson*, a worthy Member of this *Society*, that the Swiftneſs of the electrical *Effluvia* is prodigious ; that one Stroke of his Hand down the Tube, when well electrified, was felt as soon as his Hand could be at the Bottom of the Tube, through five Men standing upon electrical Cakes, and communicating with each other by a Cane, Sword, or any other Non-electric.

LXXII.

Hence it follows, that if a Tube could be always excited, and was always to be applied to the End of
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* Introduction to his Essays on Poisons, *Edit.* 3.

a proper Cord or String; the electric Matter, which is excited by Friction between the Hand and Tube, would ever be ready to exert its attractive Influence on Leaf-Gold, and such-like Things, when placed within a due Distance of the End of the String; and perhaps this may be very similar to the Motion and Action of the nervous *Æther*.

LXIII.

Thus much being premised, and it being taken for granted, that we have an *athereal Medium* in the Brain, Spinal Marrow, and all the *Capillamenta* of the Nerves, ever ready to be convey'd into the muscular Fibres, by the Power of the Will, and which *Medium* consisting of the most refined Matter in Nature; it follows, that the Motion of this nervous *Æther* may be as quick as Lightning, and also its attractive Power must be exceeding strong, by virtue of its vast Degree of Subtilty; as is evident from what Sir *Isaac Newton* * has calculated concerning the Rays of Light.

LXXIV.

From these Observations therefore, and from what has been said above concerning the Cohesion and Elasticity of the animal Fibres, I think we have great Reason to conclude, that muscular Motion does proceed from the Influence which the nervous *Æther*
has

* Opt. Qu. 23, 24.

upon the component Particles of the muscular Fibres themselves, by instantly increasing their attractive Virtue towards each, so as to make them run closer together, or, as it were, up into Heaps, as long as such an additional attractive *Medium* is in the Fibres.

LXXV.

If we look back and consider the Nature of the *Vis Restitutionis*, or Elasticity in the muscular Fibres, we shall find, that the Cause of that Property only wants to be increased, in order to overcome the distractile Force of the circulating Fluids, and the Resistance of the antagonist Muscles: Whence it follows, that if such a Power was to be increased in one Set of Muscles, and not in their Antagonists, those Muscles, whose elastic or retracting Power was increased, would be abbreviated in their Length, whilst the others would be extended and lengthen'd.

LXXVI.

When any Muscle is freed from the Power of its Antagonist, by a Wound, &c. it immediately contracts, and is not to be extended again by the Power of the Will. Whence it has been said, that Contraction is the proper State of the Muscles, and to which they always tend: But if we narrowly inspect into this Affair, we shall find, that, when a Muscle is contracted in this manner, it is no further so than the elastic restitutive Property in the Fibres is concerned: We do not find that such a Muscle is indurated, or its Belly swollen like unto what it is in

voluntary Action; for here being no Influx of the nervous *Æther* to increase the corpuscular Attraction, the Muscle is shortened only by the inherent mutual Attraction between the constituent Particles of its Fibres, without any Matter being superadded. This kind of Contraction therefore is evidently the State to which the elastic Fibres, tend by a continual *Conatus* in the component Particles to accede towards each other without the Assistance of the nervous *Æther*; so that this natural *Vis motrix* in the musculous Fibres is no more than what we mean by their Elasticity, or resilitive Property: It seems however to be demonstrated from hence, that muscular Action, and Elasticity in the Fibres, proceed from the same Cause in different Degrees; *viz.* from corpuscular Attraction.

LXXVII.

Let us now endeavour to corroborate these Arguments by some suitable Observations.

LXXVIII.

1st. From what has been said we may conceive more readily, than we know how to express, that the Will has a Power to direct the *æthereal Medium* contain'd in the Nerves, to any of the voluntary Muscles, with such a Degree of Celerity as it pleases; and to stop the Influx as suddenly.

LXXIX.

2^{dly}. It is evident that the Coats, or carnos Sub-
stance of every Fibre, must necessarily increase in its
Thicknes,

Thickness, when it abates in its Length; and what Power can produce this Effect, but such a one as increases the mutual Attraction between the constituent Particles?

LXXX.

3dly. Hence appears the Reason, why the Belly of a Muscle swells during its Contraction, notwithstanding its Dimension in general is diminish'd; for as the component Particles of each Fibre are more loosely join'd together about the Middle than towards its Extremities, which are generally tendinous, it is natural to suppose that the chief Action is between them; that is, when a Fibre grows shorter, such of its Particles which are most at Liberty run nearer together, and as the Motion of all Bodies is ever in proportion to the Impulse they receive, and the Resistance they meet with, so when the constituent Particles of the muscular Fibres are drawn into a shorter Compass, by the means above-mention'd, the Middle of the Fibres must swell either inwardly or outwardly, or both, according to the Resistances they meet with.

LXXXI.

And *lastly*, Since the Coats of the muscular Fibres do most certainly grow thicker as they contract in their Length, and yet the external Surface of the Muscle in general is diminished; it manifestly follows that their Cavities must grow less, and their

contain'd Fluids must be pressed out, in proportion to the Contraction of the Muscle.

LXXXII.

This appears upon Blood-letting, when squeezing any thing hard in the Hand will make the Blood fly out with a greater Velocity, and thereby form a larger *Parabola*.

LXXXIII.

This also accounts clearly for the Induration and Paleness of a Muscle during its Action.

LXXXIV.

And again, it follows hence, that in the Action of the Muscles there is an alternate *Diastole* and *Systole* perfectly analogous to the Action of the Heart, which greatly contributes towards pushing on the Blood in the Veins.

LXXXV.

The Muscles being contracted merely by the Influence of the nervous *Æther*, and the Influx of the *Æther* being stopt by withdrawing the *Impetus* given to it by the Power of the Will; the Reason and Manner of their Relaxation will easily appear. For since the nervous Fluid is extremely subtile, that Portion of it which is thrown into the muscular Fibres, acts but for a Moment, or the least
Space

Space of Time, so quick is it in its Motions, and so penetrating in its Nature; and no sooner is the Vigour of the Attraction over, but the Tension of the Antagonist Muscles, and the Impulse of the Blood will extend them again.

LXXXVI.

Whoever duly considers the well known Effects of magnetical and electrical *Effluvia* will be at no Loss to conceive the instantaneous Influence which the nervous *Æther* has upon the muscular Fibres.

LXXXVII.

It must be confess'd indeed, that these *Intima Naturæ*, or secret Operations in the Animal Oeconomy are all skreen'd from our Knowledge, the Agents being too subtil ever to become the Objects of our Senses, though ever so well assisted; so that we can only form our Schemes, and deduce our Arguments from such collateral Proofs, or from such *Data* as we are pretty sure are true. As for Instance; the Influence which the *Soul* has upon the *æthereal Medium* in the Nerves must be by Impulse; for though our finite Capacities are not able to comprehend the Nature of immaterial Impulse; yet nothing is more certain than that the most subtil Matter in the Universe cannot be moved without some impressed Force.

LXXXVIII.

LXXXVIII.

That the Will does exert itself after this manner, is in a good measure proved by Dr. *Stuart's* * Experiment upon a Frog, where a proper Impulse being given to the *Medulla spinalis* did excite Motion in the voluntary Muscles, though the Head was sever'd from the Body.

LXXXIX.

Hence also it appears, that the Nerves are always replete with a subtil Fluid capable of contracting the Muscles, or otherwise such an Impulse on the Beginning of the Nerves, could not have excited Motion after the Head was cut off.

XC.

And again, common Experience assures us, that tho' the Nerves are always replete with an *æthereal Medium*, yet this *Medium*, in a State of Health, never flies out at their Extremities, into the muscular Fibres, without some Impulse by the Direction of the Will: Whenever it happens to do so, Convulsions and Cramps are the natural Consequences.

XCI.

* Lectures on Muscular Motion.

XCI.

It may perhaps seem strange to some, that I have not all this while taken any Notice of the Blood, as an Agent in muscular Motion; since it has ever been reckoned some way necessary towards it. But notwithstanding this Opinion has been so long and so generally received, yet if our Scheme be the true one, it evidently appears the Blood hath nothing to do with the immediate Contraction of the Muscles.

XCII.

From the close Connection of the nervous *Capillamenta* in all or most of their Ramifications, to those of the Arteries, it seems as if the *Diaſtole* and *Syſtole* of the arterial System was some how useful to them. Perhaps it may assist in pushing on the *Succus nutritius*, or that clammy balsamic Juice which is in the Nerves, towards their Extremities; but I cannot conceive that the Blood itself is in any way assisting towards muscular Motion, except it be by keeping the Fibres warm, supple, distended, and every way ready for the Influx of the nervous *Æther*.

XCIII.

I have tied up and cut asunder both the *Carotid* and both the *Crural* Arteries of the same Dog, without destroying the Motion of one Muscle. Nothing less than laying a Ligature on the *Aorta descendens* will

will destroy the Motion of the hinder Parts; and possibly this may happen from the great Distension of the *Aorta* above the Ligature, pressing upon the Nerves which go to the lower Parts.

XCIV.

It is certain indeed, when all the Blood is intercepted the Fibres will soon collapse, and grow flaccid, and muscular Motion will cease, merely for Want of the Warmth, Suppleness, and Distension which the Muscles receive from the Blood. But what I think most reasonable is, that the Blood is no Way concerned as an efficient Cause in pursuing up and contracting the Fibres it rather by its Motion through the Muscles, acts as an Antagonist to their Contraction, by extending and distending them; for the Blood, by the *Diastole* and *Systole* of the Arteries, is continually urging on its Passage through the Muscles.

XCV.

Thus I have endeavour'd to deduce and illustrate the Cause of muscular Motion from true Principles, by pursuing only those *Laws of Nature*, which our great Philosopher Sir *Isaac Newton* has in so surprising a manner discover'd to us. But I am far from thinking this a complete Account; I know it requires more Experiments, and better Reasonings than I am Master of, to explain it as it ought; and even after all, there are, and ever will be, some Things above the Reach of our Capacities to demonstrate,

strate, any otherwise than by their Effects, or second Causes: Such are, the Nature of an immaterial Impulse; the real Existence of so subtil a Fluid as is attributed to the Nerves; and the true Causes of Attraction and Repulsion.

XCVI.

That the SUPREME BEING hath implanted an immaterial Spirit in every living Creature, for the Purposes of Sensation and voluntary Motion, I think cannot be denied by any one in his Senses: But perhaps it may not become us to be too solicitous about the *Modus* of Action betwixt the *Soul* and *Matter*; these Things being above the Reach of human Reason. It is sufficient for our Purpose, that we know the Will has a Power of determining the nervous *Æther* immediately and directly to every individual voluntary Muscle.

XCVII.

The Existence or Non-Existence of the nervous Fluid, commonly called the animal Spirits, has been a Controversy of long standing. The first Searchers into the Structure of the human Body soon found that muscular Motion depended upon the Nerves, or something within them; and this has constantly been asserted, and admitted as a known Truth. The Advocates for the Existence of animal Spirits have generally supposed that voluntary Motion was performed by a sudden Inflation of the Muscles, either by the Power of the nervous Fluid itself, or by an instantaneous Ferment with some other Fluid; and I am apt to believe, that this Doctrine proving

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inconsistent

inconsistent with many Things relating to the Animal Oeconomy, and contrary to some known Experiments, might give Rise to the vibrating Scheme, where the Existence of the animal Spirits is denied, and where it is supposed that both Sensation and muscular Motion may be performed merely by the Elasticity of the Nerves, and Contractions first of all begun in the Brain, and so communicated to the fleshy Fibres: But this is so immechanical a Notion as not to deserve an Answer; it being impossible for a vibrating Motion in one Cord or String, were it ever so elastic, to cause a Contraction in another, without the Intervention of some Fluid.

XCVIII.

I shall conclude this Lecture therefore with observing, that the Existence of an *æthereal Medium* in the Nerves is past all manner of Doubt; it being otherwise contrary to the known Laws of Nature for the Nerves to be the Cause of muscular Motion if they were solid, or did not admit the most subtil Fluid, secreted by the Glands of the Brain, to pass through them.

XCIX.

And since it is known from Experiment, that the Muscles grow less in Action, and, consequently, the constituent Particles of every Fibre must run nearer together before such a *Phænomenon* can happen; we think it very manifest that this Property of Constriction arises from the Principle of corpuscular

lar Attraction being increased and strengthened by the Influence of the nervous *Æther*; a Principle, which, from the endless Divisibility and Subtilty of Matter, we may never be able to comprehend, though we know it to exist in Nature from innumerable Observations and Experiments.

The End of the Second Lecture.

LECTURE III.

XCV.

Read April 9. 1747. **I**N Confirmation of the Truth of what has been said in the two preceding Lectures, and for a further Illustration of this Subject of muscular Motion, I beg Leave to offer some Thoughts concerning the Cause and Manner of Action in the involuntary Muscles; and after that I shall relate some Experiments, which I have made in order to illustrate our Theory in general, as far as the Nature of the Subject will admit.

XCVI.

When any Muscle, voluntary or involuntary, is fully contracted, that is, when its component Particles are drawn into the closest Contacts they are capable of, by the Influence of the *athereal Medium* in the Nerves, it is evident, from all the Laws of Matter, that they would not recede from each other again without some impressed Force. Now in all the voluntary Muscles we very well know, that when one Set of them are contracted, their Antagonists are lengthen'd, and *vice versa*; so that the *Vis Restitutionis* in all the stretched-out Fibres, and the *Momentum*

Momentum of the Fluids to enter again into the contracted Muscles, will instantly dilate and distract them, when the Impulse of the Will ceases, till an exact Equilibration is restored.

XCVII.

This being the plain Matter of Fact in regard to the voluntary Muscles; let us now endeavour to find out the Mechanism belonging to the involuntary ones, and more particularly of that very curious one the Heart.

XCVIII.

Dr. *Hoadly*, in his *Lectures on Respiration*, has manifestly shewn that the external Ranges of the intercostal Muscles appear to have all the characteristic Marks of antagonist Muscles. If you take three Ribs together, *says he*, and observe the different Ranges of the Fibres in the two intercostal Muscles, which lie on each Side the middlemost of these Ribs; you will see, at first Sight, that the internal Range in the lower Muscle, counter-acts directly the external Range in the upper Muscle.

XCIX.

The Action of the *Diaphragm* is also counter-balanc'd by the abdominal Muscles, and Contents of the *Abdomen*; which squeeze it up, in a convex Form, into the Cavity of the *Thorax*, upon every Expiration.

As

C.

As to the *Sphincter* Muscles, they seem to be always in the same natural contractile State; and whenever they are stretched out, by some superior Power, they recover their usual Dimensions merely by their restitutive or elastic Property. The same may be said of the *Stomach*, *Uterus*, *Vesica*, which contract by the same means, into a narrower Capacity, as soon as their Contents are discharged.

CI.

I shall confine my Thoughts therefore to the Action of the Heart only, as being the most perfect involuntary Muscle.

CII.

The Heart is a *Viscus* which has given the *Literati* a great deal of Trouble to find out its real Mechanism, and the true Cause of its regular Alterations of Contraction and Dilatation. I have oftentimes laid open the Breast of a Dog, and kept his Lungs playing with a Pair of Bellows, in order to observe how regularly and alternately the *Systole* and *Diastrale*, both of the Heart and its Auricles, followed each other; that is, when the Ventricles were contracted, the Auricles were dilated, and *vice versa*; so that the Auricles seem, in some measure, to act as Antagonists to the Ventricles, and the re-fluent Blood may be of the same Service to the Auricles.

ricles. But there being so much Disparity between the contractile Strength of the Ventracles and that of the Auricles, there must necessarily be some other Cause, which, when the Heart is fully contracted, makes it unbend again, or cease to contract; by which means the Auricles, though so very weak in comparison of the Ventracles, have Power enough to throw in Blood, and thereby to distend the Ventracles to a certain Degree, before they are capable of acting again.

CIII.

If we might be allowed to make an Estimate of the Difference between the contractile Strength of the Heart and its Auricles, from the Difference of their Bulk, or Quantity of Fibres, we should find it to be about *nine* to *one*; as I have observed, by weighing the Hearts of several Animals, and their Auricles separately.

CIV.

Hence it does not seem reasonable to think, that the weak Efforts of the Auricles would be sufficient to cause the *Diastole* of the Heart, without some other Assistent.

CV.

One great Use of the Auricles is, to receive a Quantity of Blood, during the *Systole* of the Heart, sufficient to fill the Ventracles again at their *Diastole*.

stole. The same may be said, in some measure, of the Veins nearest the Heart, which may be plainly seen to dilate during the Contraction of the Auricles; so that the Heart, Auricles, and Veins, have all their *Systoles* and *Diaستoles* in subordinate Degrees.

CVI.

Without such Receptacles as these it would be impossible for the Ventricles of the Heart to be fill'd from the Veins so suddenly as they are; for though the *Areas* of the transverse Sections of the Veins are much larger than those of the Arteries, yet we find, by Dr. Hales's *Hæmæstatical Experiments*, that the Velocity of the Blood in the Arteries is above *six* to *one* to that in the Veins: But since the Auricles keep receiving the Blood whilst the Heart is in its *Systole* (the Veins doing the same by the Auricles) a due Quantity of Blood is always ready to be thrown into the Heart, by the Time it is fit to receive it; for the *Diaستole* takes up two Thirds of the Space of Time between each Pulse.

CVII.

Here then we may observe that the *Momentum* of the reflux Blood acts upon, and distends the Veins nearest the Heart, whilst the Auricles are contracted; that it also dilates the Auricles, whilst the Heart is in Action; and that the Heart is in its *Diaستole*, whilst the Auricles are in their *Systole*.
But

But the great Difficulty in accounting for the *Dia-*
stole of the Heart, is from the Disproportion between
 its contractile Power, and that of the Auricles; it
 being plain, from what has been said above, that
 the *Momentum* of the Blood in the Veins is stopt by
 the Contraction of the Auricles, so that the Ventricle
 of the Heart can receive no other Impulse from
 the Blood at that time, than what is derived from
 the Contraction of the Auricles.

CVIII.

Hence therefore it follows, that if the *Systole* was
 the natural State of the Heart, and to which it al-
 ways tended with its full contractive Power, the
 Impulse of the Blood, from the Contraction of the
 Auricles, could never be able to dilate it.

CIX.

Dr. *Lower* makes the *Systole* the natural State or
 Action of the Heart, and the *Dia**stole* the violent
 one: *Boerhaave*, on the contrary, makes the *Systole*
 the violent, and the *Dia**stole* the natural State. But
 perhaps neither of these Opinions may be right, in
 the strictest Sense; for if we look back we shall
 find, that if the Fibres were not tense they could
 not be elastic; and if some Violence was not put
 upon them, by the Impulse of the circulating Fluids,
 they would not be tense: Hence it appears, that
 Elasticity proceeds from a State of Violence.

CX.

And again; When a Muscle is freed from the Power of its Antagonist, and is thereby left at full Liberty to contract, as it always will by its elastic, restitutive Property only, it does so no further than in Obedience to the common Power of Attraction between its component Particles; but in all other muscular Action, when this attractive Power is greatly increased by the Influx of the nervous *Æther*, the Constriction is carried much further, and the Muscle is more fully contracted than it ever is in the other State: Hence it follows, that Contraction, in its fullest Degree, is not the natural State of a Muscle.

CXI.

And further; When the constituent Particles of the Fibres are drawn into their closest Contacts, by the Influx of the nervous *Æther*, it requires some Force, in a contrary Direction, to elongate the Fibres again; so that Extension, or Dilatation is also a State of Violence.

CXII.

From the Whole then it appears, that neither the *Systole* nor *Diaſtole*, in a full Degree, is the natural State of the Heart; and this we shall shew more plainly hereafter by inspecting the Hearts of Animals after being bled to Death. But to proceed :

CXIII.

CXIII.

From what has been said above, it seems reasonable to conclude, that if Contraction, in its fullest Degree, was the natural State of Rest or Quiescence in the Heart; the *Momentum* of the Blood from the Contraction of the Auricles, could not be a sufficient Counterpoise. And since so many fruitless Attempts have been made to account for the *Diastole* of the Heart; from the *Impetus* of the Blood in the Veins, and from the Pressure of the Atmosphere, &c. give me Leave to propose the following *Queries*.

CXIV.

1st. May not the Heart be a compound Muscle; that is, may it not have its Antagonist within itself? Or, in other Words, are not some of its Fibres so ranged, that whilst one Set of them is contracted and shorten'd, others may be stretched out; analogous to the Action of the intercostal Muscles, or any other Muscles with their Antagonists?

CXV.

2^{dly}. Is the nervous *Æther* transmitted from the Brain to the Heart in a pulsatory Manner, at equal Distances of Time; or may it be supposed to move uniformly through the Nerves, and some Interruption is given to its Influx into the muscular Fibres, when the Heart is in its *Systole*?

CXVII.

3dly. Does not the *Diastole* of the Heart depend upon an Abatement of the Tension in the contracted Fibres; a Motion of Resitution in such as are over-stretched; and the Influx of the Blood conjunctly?

CXVIII.

Without some such Mechanism as this, no Power that we know of, belonging to the animal Oeconomy, would be able to cause the *Diastole* of the Heart: But if such a Structure, as is above mention'd, could be proved, no more Difficulty would attend the Explication of it than that of the voluntary Muscles.

CXIX.

In dissecting the Heart we find a great many different Orders or Series of Fibres, variously contorted, and running in contrary Directions; so that, for ought we know, it may be an *Epitome* of muscular Construction in general.

CXX.

We may here observe what Care *Nature* has taken to prevent too great a Dilatation in the *Diastole* of the Ventracles, the right one especially, as being the weakest, by forming the *Papillæ*, or *Columnæ*, which run
from

from the *Septum*, or middle Partition, to its opposite Sides; whereby they act as so many Braces in the *Diaſtole*, and when they contract, they alſo aſſiſt in the *Syſtole*. And perhaps it may not be the moſt improbable Conjecture to think; that as much Care may have been taken in providing a ſufficient Number of Fibres, or little Muſcles, which may be ſo formed as to act in the *Diaſtole*, as Antagoniſts to thoſe which occaſion the *Syſtole*.

CXXI.

The Hearts of Frogs, Vipers, Eels, &c. ſeem to evince the Reaſonableneſs of this Conjecture, by continuing their *Syſtoles* and *Diaſtoles* after they are taken out of the Body; when there is no reſluent Blood to dilate the Ventracles, and, conſequently, if there were no Fibres upon the Stretch, when the Heart is contracted, which, by their Elafiicity, or reſtitutive Power, did pull back, or elongate ſuch as were contracted, there could not poſſibly be any *Diaſtole* in ſuch Circumſtances.

CXXII.

We are aſſured by Mr. Boyle, in his *Phyſico-Mechanical Experiments*, that the Heart of an Eel hath continued to beat an Hour, in an exhausted Receiver; after which, finding its Motion very languid, and almoſt ceaſed, by breathing a little upon that Part of the Glaſs where the Heart was, it quickly regain'd Motion; and an Hour after that,
finding

finding it almost quite gone, he was able to renew it, by the Application of a little more Warmth.

CXXIII.

The same *illustrious Author* further assures us, that he has sometimes cut the Heart of a Flounder transversely, into two Parts; and freeing each from the Blood it contain'd, he observed, for a considerable Time, that both of them together continued their former Contraction and Relaxation. And once, thus cutting one into several Pieces, he found, to his Surprise, that they not only moved as before, but that even the Whole, thus separated, long preserved the same Succession of Motion, as appeared therein whilst coherent.

CXXIV.

Now can the *Diaſtole* of the Heart, in these Experiments, be accounted for upon any other Principles than those we have laid down? Here was no Impulse from the reflux Blood to dilate the Auricles, or to distend the Ventracles. The Pressure of the Atmosphere was also quite taken away in the first Experiment, and could not possibly be of any Service in the last; and yet the *Diaſtole* continued.

CXXV.

Can the same Fibres which are contracted, have it in their own Power to fly out again to their usual Lengths? If this cannot be, what Power is there

there in a Heart, taken out of the Body, to unbend itself, or to dilate its Ventricles, after they are once contracted, unless we suppose some of its Fibres to act as Antagonists to others?

CXXVI.

We have good Reason therefore to believe that some Fibres of the Heart are always stretched out beyond their natural Tone, when others are contracted; so that, by their elastic, restitutive Property, they do act as Antagonists in a certain Degree.

CXXVII.

In regard to the *Systole*, in such Hearts as are taken out of the Body, and cut into several Pieces, we conceive, that as long as Warmth and Moisture remain, so long may the *æthereal Matter* in the Nerves, continue to fly into the Fibres, and contract them; and when it ceases, more Warmth, or a gentle Impulse (even with the Point of a Needle only) will revive the Motion.

CXXVIII.

Hence we may, in some measure, discover the amazing Subtlety of the nervous *Æther*; when such very small Sections of the Nerves, as in the above-mention'd Experiment upon the Heart of a Flounder, should contain Matter sufficient for so many Contractions.

CXXIX.

CXXIX.

Let us now return to our *second Query*, and examine whether the nervous *Æther* is transmitted from the Brain to the Heart, in a pulsatory Manner, at equal Distances of Time; or whether some Interruption is only given to its Influx into the muscular Fibres, when the Heart is in its *Systole*.

CXXX.

In order to understand this, we must look back and consider, that, according to our Theory, if the *æthereal Medium* in the Nerves was perpetually flying into the muscular Fibres of the Heart, it would be constantly contracted, notwithstanding the *Momentum* of the Blood, the Contraction of the Auricles, or the *Vis Restitutionis* in the stretched-out Fibres. Hence then it is evident, that the alternate Contractions and Dilatations of the Heart proceed from an alternate Influence of the nervous *Æther*; but how this Alternation happens, when the Nerves which supply the Heart are not, in the least, under the Direction of the Will, is the Difficulty we labour under.

CXXXI.

In all the Nerves which supply the voluntary Muscles, it is certain there are Restrictions in some Parts of them which the *æthereal* Matter is not able to dilate without an additional Impulse from the Will;

Will; or otherwise Cramps and Convulsions would perpetually happen. But in those which supply the Heart, the Motion of the *Æther* through them cannot have any Assistance or Impulse from the Will, as nor being in the least under its Influence; so that the Vibrations of the *Meninges* of the Brain, and the Dilatations of the Arteries may be supposed to be the Agents which propel the *Æther* towards the Heart.

CXXXII.

Hence then it seems to follow, that the alternate Contractions of the Heart may proceed from the alternate Impressions made on the Nerves, by the *Meninges* of the Brain, and Dilatations of the Arteries.

CXXXIII.

Upon opening the Skulls of living Animals, the *Dura Mater* may plainly be seen to have its *Systoles* and *Diastoles* corresponding to those of the Arteries; but since the Heart continues to beat after the Head is cut off, or even after it is taken out of the Body, where there cannot be any alternate Succussions made on the Nerves by the *Meninges* of the Brain, or by the Pulsation of the Arteries, it seems reasonable to believe that this Alternation is occasion'd by some Impediment being given to any further Influx of the *Æther* into the muscular Fibres of the Heart, when it is fully contracted; or otherwise, the Heart would constantly remain in a

State of Contraction, as long as there was any *athereal Matter* flying from the Nerves.

CXXXIV.

If we consider in how many different Directions the muscular Fibres of the Heart run, how much they are corrugated, thickened, and swelled, when fully contracted, and how strong and uniform the Pressure must be in their greatest Degree of Action; it may not perhaps appear unreasonable to think that the Extremities of the Nerves, which are inserted into every Fibre, and which are extremely small and tender, may be pressed upon and squeezed, so as to prevent the Influx of the *Æther*, till the Pressure is abated, or till the Fibres are extended again to their usual Lengths.

CXXXV.

What seems to evince the Reasonableness of this Supposition is the Nature of the *Shaking Palsy*; where the voluntary Muscles immediately become involuntary ones, so far at least, as to be alternately contracted and relaxed without the Consent or Direction of the Mind.

CXXXVI.

Now this Distemper we believe to proceed from a particular Weakness in the Nerves, whereby those little Restrictions in them, which keep the *athereal Matter* within due Bounds, in a State of Health,
are

are so far weaken'd and destroyed, that the *Æther* has a Power of flying into the muscular Fibres without any Impulse or Direction from the Will, after the same manner it does into the Heart. If therefore no Interruption was to be given to the Influx of the nervous *Æther* by the Muscles themselves, when they were contracted, it would follow, that if the *Flexors* of any Limb were to be first contracted, the *Extensors* would not be able to recover the *Equilibrium*, and to be contracted in their Turn, without the Assistance of the Will; for if our Doctrine be right, *viz.* that muscular Motion proceeds from the constituent Particles of the Fibres being drawn into closer Contacts by the attractive Influence of the nervous *Æther*, it necessarily follows, that if the same Quantity of *Æther* was continually to fly into a Muscle already contracted, it would have a greater Influence on the component Particles so approximated, than on others in the antagonist Muscles, which are distracted, and consequently touch each other in fewer Points.

CXXXVII.

Hence it seems to be evident that some Impediment is given to the Influx of the nervous *Æther* when the Muscles are contracted, or otherwise that they would always remain so; for, though the Will may be able to remove such little Impediments, and to keep the voluntary Muscles in a State of Contraction for a considerable Time; yet since the voluntary Muscles, when affected with a Palsy, are regularly and alternately contracted, and have their

Systoles and *Diafoles* analogous to the Heart and its Auricles, I think we have good Reason to conclude, that the same Principles which contract and dilate the voluntary Muscles, in the above-mention'd Condition, are the Principles which occasion the *Systole* and *Diafole* of the Heart, with this Difference only, that the Influx of the Blood into the *Sinuses* of the Heart, is what no other Muscle in the Body has or receives; and without Doubt this may truly be reckon'd the greatest Assistant in dilating the Ventricles of the Heart, after the attractive Influence of the nervous *Æther* ceases, and the *Æquilibrium* is restored between the stretched-out Fibres and those which were contracted.

CXXXVIII.

What has been said seems greatly to evince the Truth of our *third* and *last* Supposition; *viz.* that the *Diafole* of the Heart may depend on an Abatement of Tension in the contracted Fibres, a *Vis Restitutionis* in such as are over-stretched, and the Influx of the Blood conjunctly.

CXXXIX.

Give me Leave to relate two or three Experiments which I have made, in order to illustrate the foregoing Theory, and then I shall conclude.

CXLI.

EXPERIMENT I.

Having observed that the Ventricles of the Hearts of all Animals, when bled to Death, are dilated, or stand wide open to a certain Size, though there happens to be very little Blood in them, it seems as if the *Diastole*, in a certain Degree, was the last Motion of the Heart. In order to know the Truth of this, I open'd the *Thorax* of a Dog, and kept his Lungs playing with a Pair of Bellows, that I might perfectly see the several Actions of the Heart and its Auricles.

CXLII.

The Auricles seem'd to me to begin the Motion, and the *Systole* of the Heart always instantly followed that of the Auricles. Then the *Apex* and Sides of the Heart sunk down, and were lengthen'd of their own accord, before any Blood was thrown into the Ventricles, from the Contraction of the Auricles; for there was oftentimes more than double the Time taken up in the *Diastole* of the Heart, than the *Systole* both of the Auricles and Ventricles required.

CXLIH.

If I desisted from blowing fresh Air into the Lungs for some little Time, the Heart would lie still, and yet I could recover its Motion again, by
strongly

strongly distending the Lungs. In this Action I never could discern that the Heart began the Motion, but the Auricles always contracted first, and then the Heart immediately afterwards; though, at last, I saw several Contractions of the Auricles, which were not succeeded by any Motion of the Heart.

CXLIV.

I must not forget to mention, that in another Dog I saw several *Systoles* and *Diaستoles* of the Heart after I had purposely cut asunder both the *Vena Cava's*; and could plainly perceive the Ventricles to relax and open themselves, when very little or no Blood could possibly flow into them. This however is much more easily seen in the Heart of a Viper, when taken out of the Body, which will continue its *Systole* and *Diaستole* for a long time; and if it ceases to beat ever so often, and you renew its Motion again and again, by breathing upon it, &c. You may observe that the Auricle always contracts before the Ventricle, and that the *Diaستole* is the last Motion, though there is no Blood to distend the Heart.

CXLV.

The Capacity of the right Ventricle of the Dog's Heart, in the above Experiment, as it open'd of its own accord, was something more than a cubic Inch, as I found, by pouring in melted Wax from a Ladle, without any Pressure from a perpendicular
Height,

Height, after the Auricle and Blood-vessels were cut off transversely.

CXLVI.

EXPERIMENT II.

Taking the Heart out of an Ox as soon as I possibly could after he was kill'd, and having cleansed it from the Blood, by washing it in warm Water, I fill'd both the Ventricles with melted Wax, without any distending Force more than by pouring it from the Ladle. The Heat of the Wax seem'd rather to contract the Fibres, and to lessen the Capacities of the Ventricles; for some of the Wax kept running out from the Heart after I had done pouring it from the Ladle.

CXLVII.

The Capacity of the right Ventricle was equal to $5\frac{1}{2}$ cubic Inches. The Capacity of the left Ventricles was not quite 5 cubic Inches.

CXLVIII.

From these Experiments it manifestly appears, that the last or restitutive Motion of the Heart is to dilate or open the Ventricles, and that without any Assistance or Impulse from the reflux Blood.

CXLIX.

CXLIX.

Dr. *Hales* * injected the left Ventricle of the Heart of an Ox from a Column of melted Wax $4\frac{1}{2}$ Feet high, which distended the Capacity of it to 12. 5. cubic Inches. Now supposing the Impulse of the reflux Blood to be equal to a Column of melted Wax $4\frac{1}{2}$ Feet high, and that in every *Dia-stole*, whilst the Ox was alive, the left Ventricle was distended to the Capacity of 12. 5. cubic Inches, yet we may observe that the Heart, immediately after each *Systole*, relaxes and dilates its Ventricles to a certain Degree, by its own Mechanism, and to whatever Capacity the Ventricles are afterwards dilated, it must necessarily proceed from the Impulse of the Blood only; all which is perfectly agreeable to our *third Query*, viz. that the *Dia-stole* of the Heart may depend upon an Abatement of the Tension in the contracted Fibres, a Motion of Restitution in such as are over-stretched, and the Influx of the Blood conjunctly.

CL.

EXPERIMENT III.

I took the Heart out of a live Viper, and placing it upon a Piece of writing Paper, I found it beat
at

* *Hæmastatics*, pag. 25.

at the rate of 24 or 25 Pulsations in a Minute, for three or four Minutes. After this I laid the Paper upon the Palm of my Hand, the Warmth of which increased the Number of Pulses to 37 the first Minute, and to 48 the second. Last of all I put it into warm Water, a Degree or two warmer than the Blood, where it beat 87 Pulses the first Minute, and afterwards declined in its Motion more and more till it quite ceased.

CLI.

May we not from hence observe what vast Influence *Heat* had upon the nervous *Æther* to make it fly so quick into the Heart as to increase the Pulse to almost four times their usual Number? How far the Heat in some sort of Fevers may quicken the Pulse, is not to our present Purpose to enquire.

CLII.

It is amazing to think that such very small Portions of the Nerves, as were cut out with the Heart in this Experiment, should contain Matter sufficient for so many Contractions; and that it did not all of it instantly fly out from the wounded Ends, even before it was put into warm Water.

CLIII.

How far these Experiments may serve to illustrate and confirm the Truth of our Theory of muscular Motion, is very humbly submitted to the candid

I Judgment

Judgment of this *Honourable* and most *Learned Society*; and I shall think myself well recompensed for my Pains, if it so far meets with their Approbation as not to contain any thing inconsistent with true Philosophy, or to any of the known Laws of the Animal Oeconomy.

F I N I S.